

NASA-Evolving to Ada: Five-Year Plan

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RECOMMENDATIONS MADE BY THE Ada AND SOFTWARE
MANAGEMENT ASSESSMENT WORKING GROUP (NASA)
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National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

**NASA — EVOLVING TO ADA:
FIVE-YEAR PLAN**

**A Plan for Implementing Recommendations
Made by the
Ada and Software Management Assessment Working Group**

April 1989

**National Aeronautics and Space Administration
Goddard Space Flight Center
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FOREWORD

At their March 1988 meeting, members of the National Aeronautics and Space Administration (NASA) Information Resources Management (IRM) Council expressed concern that NASA may not have the infrastructure necessary to support the use of Ada for major NASA software projects. Members also observed that the agency has no coordinated strategy for applying its experiences with Ada to subsequent projects (Hinners, 27 June 1988).

To deal with these problems, the IRM Council chair appointed an intercenter Ada and Software Management Assessment Working Group (ASMAWG). They prepared a report (McGarry et al., March 1989) entitled *Ada and Software Management in NASA: Findings and Recommendations*. That report presented a series of recommendations intended to enable NASA to develop better software at lower cost through the use of Ada and other state-of-the-art software engineering technologies. The purpose of the present document is to describe the steps (called *objectives*) by which this goal may be achieved, to identify the NASA officials or organizations responsible for carrying out the steps, and to define a schedule for doing so.

This document sets forth four goals:

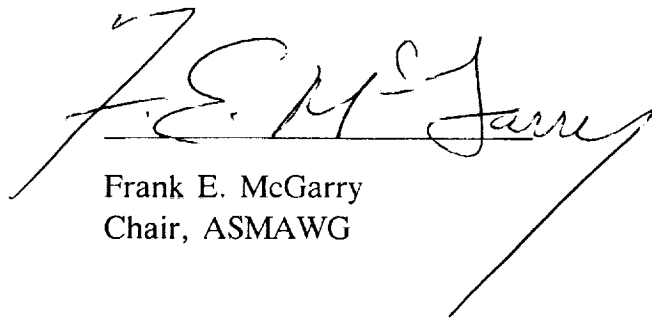
- Adopt agency-wide software standards and policies
- Use Ada as the programming language for all mission software
- Establish an infrastructure to support software engineering, including the use of Ada, and to leverage the agency's software experience
- Build the agency's knowledge base in Ada and software engineering

Each of the four main sections of this document deals with one of the goals and the objectives that fall under it. Appendix A presents a schedule for achieving the objectives and goals.

Since the abolishment of the Office of the Chief Engineer, it appears that NASA has lacked an organization chartered to oversee the agency's software engineering and agency-level software standards, policies, and guidelines. During the development of this plan, the ASMAWG concluded that the apparent lack of such an organization is a serious shortcoming of the infrastructure supporting software management in the agency. If such an

office were (re)established, or if a charter for such duties were added to that of an existing office, this plan could be more effectively implemented and sustained.

Certain of the objectives set forth in this plan would more suitably be assigned to such a headquarters office: specifically, Objectives 1.1, 1.2, 2.1, 3.1, 3.2, and 4.3. In the absence of such an office, the plan assigns responsibility for the attainment of each objective to an existing organization. For example, the Software Engineering and Ada Implementation Task Force (SEAITF), which is responsible for implementing this 5-year plan and advising the centers about Ada and software engineering (Objective 3.1), has been assigned to the IRM Council; but it would more appropriately be assigned to a headquarters engineering office.

A handwritten signature in cursive script, reading "F. E. McGarry". The signature is written in dark ink and is positioned above the printed name and title.

Frank E. McGarry
Chair, ASMAWG

Table of Contents

Goal 1: Develop Policies and Standards	1
Objective 1.1: NASA Management Instruction Mandating Ada	1
Objective 1.2: Standards	2
Objective 1.3: Risk Management	3
Objective 1.4: Software Development Environments	4
Objective 1.5: Contractor Incentives	5
Goal 2: Use Ada for All Mission Software	7
Objective 2.1: Three-Phase Transition	7
Goal 3: Establish Support Organizations	11
Objective 3.1: Software Engineering and Ada Implementation Task Force	11
Objective 3.2: Software Process Engineering Task Force	12
Goal 4: Develop Knowledge Base	15
Objective 4.1: Coordination of Research and Development	15
Objective 4.2: Training	16
Objective 4.3: Software Measurement Program	17
Appendix A — Schedule	19
Appendix B — Persons Consulted	33
References	35
Glossary of Acronyms	37

Goal 1: Develop Policies and Standards

Develop and adopt a set of agency-wide software policies and standards to support the use of Ada and state-of-the-art software engineering.

Objective 1.1: NASA Management Instruction Mandating Ada

Issue a NASA Management Instruction (NMI) that states that Ada is to become the standard programming language for NASA mission software.

Plan

Our definition of *mission software* is as follows:

Mission software is all software that is critical to the design, planning, operation, control, or testing of any NASA flight project. It comprises all flight software and all ground software that directly interface with the flight systems or could affect mission planning, control, or operations. Mission software includes, for example, all software used in flight planning, flight dynamics, mission control, and flight readiness. It also includes all software used to simulate, model, or test any of the foregoing software functions.

The NMI should contain an official definition of mission software similar or identical to that above, list categories of software to which the NMI does not apply, and specify a process for obtaining a waiver. It should also state that NASA will evolve to the use of Ada for all mission software through a three-phase process (Objective 2.1).

Responsibility

Code NT (specifically, the Information Resources Management (IRM) Council).

Goal 1: Develop Policies and Standards

Objective 1.2: Standards

Develop and adopt tailorable standards for software development, management, acquisition, and assurance.

Plan

These standards should apply to all NASA software. They should be developed with a view to general software engineering principles and NASA's specific needs. They should not specify the details of the development process but should concentrate on the products to be developed and the reviews at which compliance of these products with the required standards is to be demonstrated and assessed. The standards may, however, specify high-level requirements for such processes as configuration management, quality assurance, and the collection and reporting of metrics. The management standard should include a requirement for developing and implementing a risk management plan for all critical software projects (Objective 1.3).

The standards should be able to be tailored by adapting specific sections to fit the needs of a specific project. Either the NASA project manager or the contractor may initiate proposals for tailoring. The NASA project manager should have the authority to approve tailoring.

Representatives from private industry should review draft standards before their final approval. In addition, standards should be subject to periodic revision in light of changing software technology.

Responsibility

Code QR.

Goal 1: Develop Policies and Standards

Objective 1.3: Risk Management

For any “critical” software project, require managers to develop and implement a risk management plan.

Plan

NASA should develop and adopt a policy requiring risk management plans for critical software projects. The purpose of such a plan is to assess software development risks and then control them through risk management planning, risk monitoring, and risk resolution.

The new agency-level standard for software management (Objective 1.2) should contain a requirement to develop and implement risk management plans. It should also define the criteria for classifying projects as “critical” and describe the format and content of these plans. It should state that risk management plans are to be approved and monitored at the center level. A handbook containing guidance for developing and implementing risk management plans should be available to project managers. Each center should develop an approach for approving and monitoring risk management plans.

Responsibility

Code QR.

Goal 1: Develop Policies and Standards

Objective 1.4: Software Development Environments

Evolve toward a common software support environment.

Plan

NASA should develop a set of functional requirements for a NASA software support environment. The requirements analysis should be based on a review of the requirements for the Space Station Freedom Program Software Support Environment (SSE) and other environments and on experiences gained from designing and using these environments. NASA should eventually impose the functional requirements on all in-house and contractor software support environments for mission software. In addition, NASA should develop an environment that meets the functional requirements.

The common environment should be developed using the following approach:

1. The Software Engineering and Ada Implementation Task Force (SEAITF) (see Objective 3.1) should define the functionality required for a NASA-wide software support environment.
2. The SEAITF should produce a high-level report describing "Concepts, Capabilities, and Architecture of the NASA Software Support Environment."
3. Code RC should support research into concepts of the software support environment.
4. Code RC should support the design and implementation of a prototype environment.
5. Codes E, M, S, and T should ensure that one or more centers build or use full operational environments based on the concepts developed by Code RC.

Responsibility

Code RC.

Goal 1: Develop Policies and Standards

Objective 1.5: Contractor Incentives

Establish an Ada incentive program for NASA software contractors.

Plan

NASA should first determine what the largest barriers are to contractors' adoption of Ada and state-of-the-art software engineering. These would probably include such factors as the costs of training or hiring Ada software engineers; the costs of acquiring or developing an Ada software support environment; the inherent risks of living near the cutting edge of technology; and organizational inertia. In particular, NASA should determine the principal barriers to software reuse.

NASA should then develop a plan for overcoming these barriers through changes in the acquisition process. The plan should include considering a contractor's Ada and software engineering experience in evaluating proposals; sharing the costs of training and other transition activities; sharing the costs of acquiring or developing tools; schedules and award fees that promote readiness to use Ada at specified stages of a contract; and mechanisms by which a contract can encourage reuse.

Responsibility

Code H.

Goal 2: Use Ada for All Mission Software

Use Ada as the programming language for all mission software.

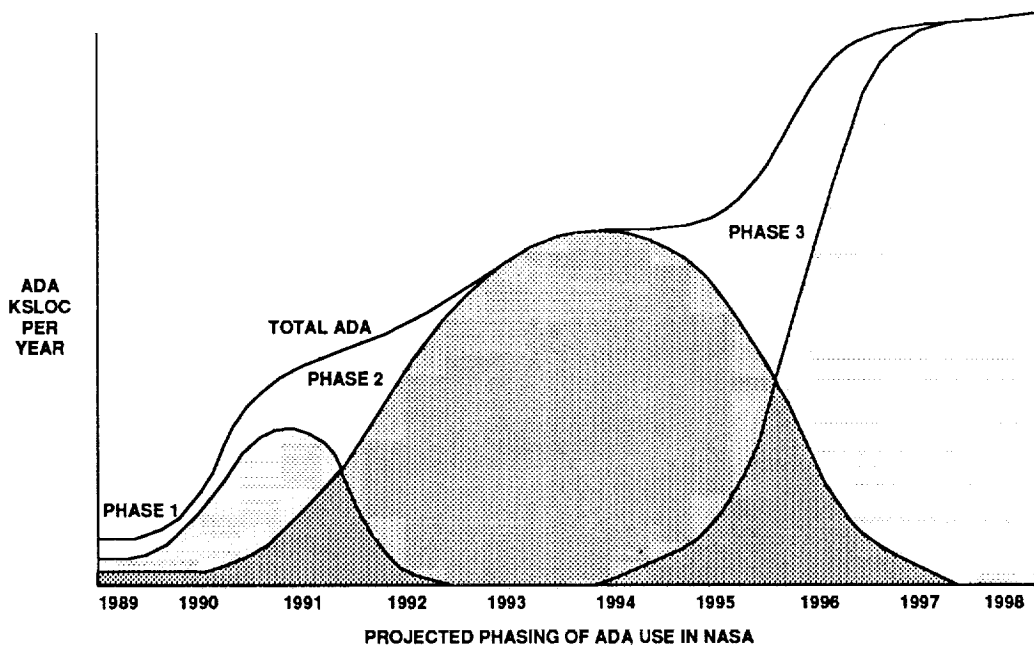
Objective 2.1: Three-Phase Transition

Carry out a phased transition at each center.

Plan

NASA should evolve to Ada through a three-phase process extending from 1989 through 1998. This phased approach will permit Ada technology and the agency's Ada capabilities to mature before NASA begins using the language as a matter of general policy on large, critical projects. It also will allow NASA to reconsider the policy periodically on the basis of experience gained. The phases should begin no later than the beginning of the following fiscal years (FY):

FY 1990	Pilot projects
FY 1992	Selected production software
FY 1995	Expanding categories of mission software



Goal 2: Use Ada for All Mission Software

By the beginning of FY 1998, all new mission software should be under development in Ada.

In Phase 1, NASA and contractor personnel should acquire the training and experience needed to use Ada on production projects. During this period, NASA personnel should participate in the Ada and software engineering training programs specified in their center's transition plan. They should also participate in pilot projects involving relatively unsophisticated and noncritical systems or parts of systems, for example, tools, benchmarks, prototypes, simulators, and test drivers. NASA personnel should manage these projects and also participate in some or all of the design and implementation. Participants in such projects should record lessons learned that may be applicable to future projects. Such projects will provide a basis for developing standards and guidelines concerning Ada management and development techniques. These projects will also absorb the 10- to 30-percent overhead that is expected in initial Ada projects because of learning curves and other transition costs (Reifer, December 1987).

In Phase 2, NASA should gain experience in using Ada on large, production projects. Projects should establish methods of measurement to capture the results of using Ada and other software engineering technologies (Objective 4.3). Projects, centers, and the agency should refine software standards and guidelines in light of experiences on these initial production projects. Phase 2 projects will also provide feedback on the most effective techniques for managing software risks.

In Phase 3, each center should gradually widen the scope of Ada use until it encompasses all new mission software by FY 1998. In Phases 2 and 3, a center should widen the scope of Ada use within a given category of software in order to maximize opportunities for reuse.

The first step in attaining this objective is the development of a three-phase Ada transition plan for NASA as a whole. Each center should then develop a more detailed plan that is compatible with the agency plan, though it need not have exactly three phases. Each of the center's transition plans should address all the points described by "A Model for Transition to Ada" in Section 4 of McGarry et al. (March 1989). The plan should explain how the center will adapt the agency-level core training curriculum (Objective 4.1) to meet the needs of the center's personnel in software engineering and Ada. The centers' transition plans should be submitted to the SEAITF and updated every 2 years during the Ada transition period.

Both the agency-level and center-level plans should define criteria for determining when each phase should begin. These criteria should at least

Goal 2: Use Ada for All Mission Software

require that the current phase has demonstrated that the center and its contractors have adequate training, Ada environments, and ability to manage Ada risks for the projects envisioned for the next phase.

Responsibility

Code NT. The center directors should be responsible for developing compatible Ada transition plans for their centers and demonstrating successful completion of each phase.

Goal 3: Establish Support Organizations

Establish an infrastructure to support software engineering, including the use of Ada, and to leverage the agency's software experience.

Objective 3.1: Software Engineering and Ada Implementation Task Force

Establish a Software Engineering and Ada Implementation Task Force.

Plan

An intercenter task force, the SEAITF, should be established. It should be responsible for implementing this 5-year plan and advising the centers about Ada and software engineering.

Preferably, the SEAITF should be organized by a permanent headquarters organization that is responsible for setting agency-wide software engineering standards, policies, and guidelines (see Foreword). However, since no such permanent organization yet exists, we are recommending that the task force report to Code NT in the interim.

The SEAITF should consist of about 10 senior software engineers representing a broad spectrum of agency centers and functions. The chair of the SEAITF should be appointed by the chair of the IRM Council and should make quarterly reports to the IRM Council.

The chair of the IRM Council should appoint the other members of the SEAITF from candidates submitted by the center directors. Members should serve terms of 2 to 4 years and should devote 50 to 100 percent of their time to the SEAITF, which should meet about once per month.

The SEAITF should operate for at least the first 5 years of NASA's transition to Ada. After 5 years, the chair of the IRM Council should determine whether the SEAITF should be dissolved or should be extended for 2-year intervals, possibly at a reduced level of support.

Responsibility

Code NT (specifically, the IRM Council).

Goal 3: Establish Support Organizations

Objective 3.2: Software Process Engineering Task Force

Establish a Software Process Engineering Task Force (SPETF) to support the evaluation and improvement of the agency's software acquisition and in-house development processes.

Plan

Members of the SPETF should be trained in the Software Engineering Institute's method for assessing software engineering capabilities (Humphrey et al., September 1987). They should then adopt this method, or some similar one, for the internal assessment of NASA's software engineering and management capabilities. The SPETF should also develop an analogous method for evaluating NASA's software acquisition processes.

The duties of the SPETF should include the following activities:

- Developing criteria, questions, and analytical techniques for evaluating the agency's software acquisition and in-house development processes
- Conducting assessments of organizations at various NASA centers
- On the basis of the assessments, formulating recommendations about how the organizations can improve their current processes
- Training personnel at the centers to conduct their own assessments

The SPETF's assessments and resulting recommendations will not be audits or personnel evaluations but mechanisms to stimulate continual growth of NASA's software engineering capabilities.

The SPETF should consist of 10 to 15 senior software engineers representing a broad spectrum of agency centers and functions. The SPETF chair should be appointed by the chair of the IRM Council and should make quarterly reports to the IRM Council. The chair of the IRM Council should appoint the other members of the SPETF from candidates submitted by the center directors. They should serve terms of 2 to 4 years.

It would be preferable for the SPETF, like the SEAITF, to be attached to a permanent headquarters organization responsible for the agency's software engineering. Since no such headquarters organization currently exists, in the interim the SPETF should be an intercenter task force that reports to the IRM Council.

Goal 3: Establish Support Organizations

Once the SPETF has developed the assessment criteria, questions, and procedures, each member should contribute about 40 percent of his or her time to the work of the SPETF. In addition to visiting centers to conduct assessments, the SPETF should meet quarterly to coordinate its activities. After performing a few assessments itself, the SPETF should spawn other groups to perform other assessments.

The IRM Council should evaluate the effectiveness of the SPETF every 2 years and take any necessary corrective actions.

Responsibility

Code NT (specifically, the IRM Council). The other program offices (especially Codes E, M, S, and T) should take an active role.

Goal 4: Develop Knowledge Base

Build the agency's knowledge base in Ada and software engineering.

Objective 4.1: Coordination of Research and Development

At the agency level, plan and coordinate software research and development, more of which should pertain to Ada.

Plan

The software engineering research at the centers should be coordinated by a single agency-level research office so that it becomes part of an integrated research program.

In addition, the agency's research efforts that pertain to Ada should be expanded. The main thrust of this research for the next 5 years should be experimentation, measurement, and evaluation of Ada-related technologies. NASA Ada research should not duplicate private-sector efforts such as the development of compilers. Rather, it should address the implications of Ada and related software engineering technology for NASA applications. It should include such topics as standards and methods, portability, reuse, and Ada's effect on management practices.

Code RC should identify Ada as a major area of its research program, the NASA Initiative in Software Engineering (NISE). Code RC should also review all completed Ada research in NASA and produce a report on the results and implications of these studies so that the lessons learned from them are not lost. Code QR should consider this information in developing software standards and guidelines (Objective 1.2).

Responsibility

Code RC. Program offices such as Codes E, M, T, and S should work with Code RC in infusing resulting technology into NASA missions.

Goal 4: Develop Knowledge Base

Objective 4.2: Training

Develop and implement an agency-wide core curriculum in software engineering and Ada. Each center should adapt the core curriculum to its specific requirements.

Plan

NASA should create an agency-wide core curriculum that addresses such topics as software management, life cycles, quality assurance, configuration management, and computer-aided software engineering. It should include sequences of courses recommended for different categories of personnel, that is, well-defined tracks for such categories as managers, developers, and quality engineers.

Code ND should begin by defining the agency's needs for training in the areas of software development, management, acquisition, and assurance. It should also assess existing NASA curricula. It should then define a new NASA curriculum in Ada and software engineering and should define tracks for NASA personnel. This curriculum should be coordinated with contractors' curricula in these areas.

The centers should adapt the agency-level curriculum to their needs and implement it. Managers should ensure that their personnel take sequences of courses suited to their backgrounds and responsibilities and that they have opportunities to apply the course material to projects. The centers' courses should be available to headquarters personnel.

Responsibility

Code ND. In each center's Ada transition plan, the center's education office should adapt the core curriculum to that center's needs.

Goal 4: Develop Knowledge Base

Objective 4.3: Software Measurement Program

Establish an agency-wide program to collect and use software metrics.

Plan

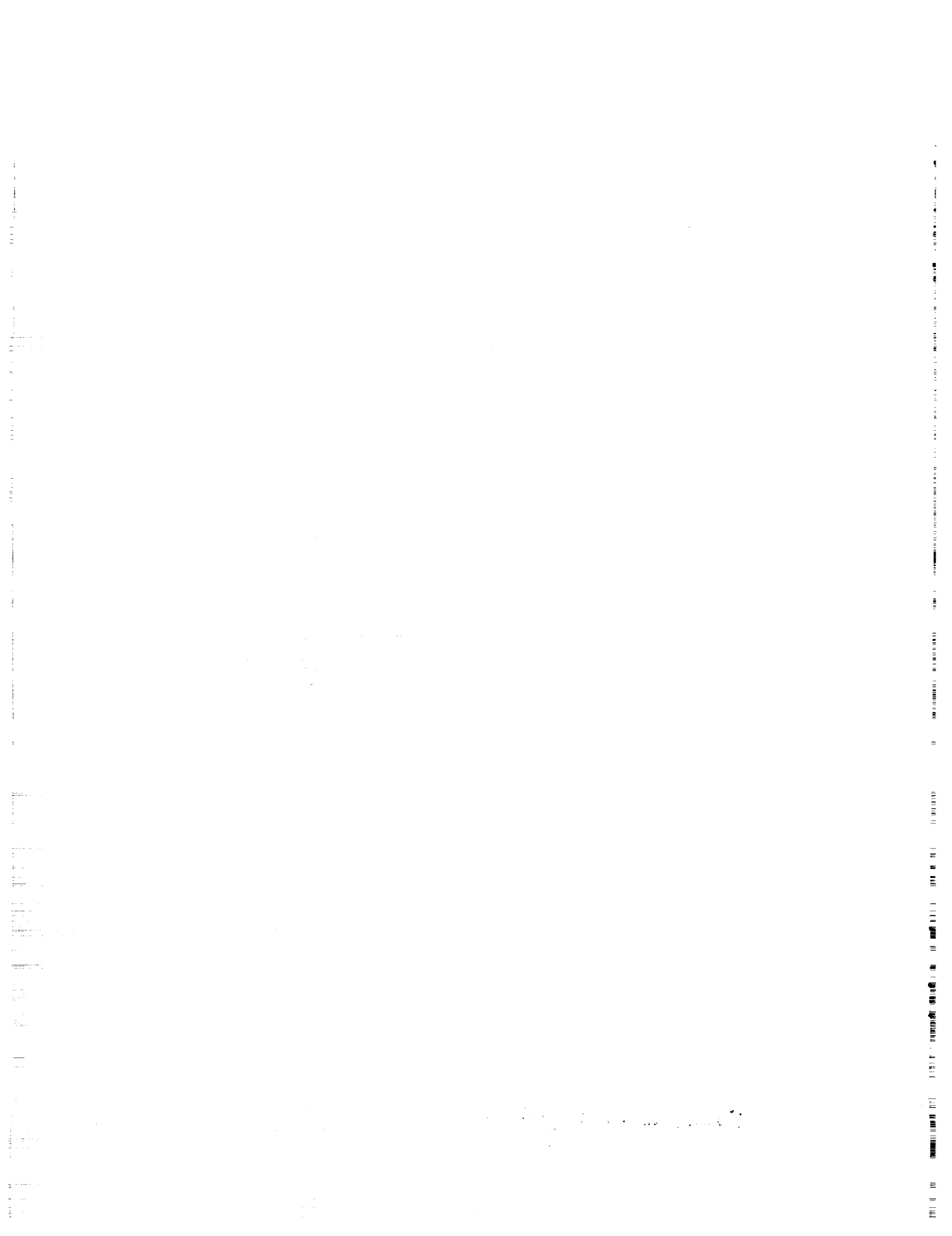
NASA should have a standard set of software metrics and a policy that requires all mission software development projects to collect and store them. These metrics should be studied and used in continuing efforts to improve NASA's software development processes by identifying their strengths and weaknesses.

Code NT should begin by defining the software measurement program, using experiences gained by the Goddard Space Flight Center Software Engineering Laboratory (SEL). Code NT should then develop a handbook defining metrics and methods of collecting and storing them. Initially, the metrics program should focus on the effectiveness of Ada and related software engineering methods and tools. The metrics should be simple. For example, they might only measure effort and error frequencies. Following the publication of the handbook, the centers should establish procedures for collecting, storing, and interpreting these metrics.

Because of its experience in sponsoring SEL research, Code T should play an active role in the measurement program. Code RC should participate because of the measurement program's relevance to NASA's software research.

Responsibility

Code NT.



Appendix A — Schedule

Appendix A — Schedule

<p>GOAL 1: Develop and adopt a set of agency-wide software policies and standards to support the use of Ada and state-of-the-art software engineering.</p> <p>OBJECTIVE 1.1: Issue a NASA Management Instruction that states that Ada is to become the standard programming language for NASA mission software.</p> <p>RESPONSIBILITY: Code NT (specifically, the IRM Council)</p>												
ACTIVITY/MILESTONE	FY89		FY90		FY91		FY92		FY93		FY94	
Develop required NMI			▽									
Review and approve NMI				▽								
Approve and issue NMI (Administrator)				▽								

Appendix A — Schedule

GOAL 1: Develop and adopt a set of agency-wide software policies and standards to support the use of Ada and state-of-the-art software engineering.																		
OBJECTIVE 1.2: Develop and adopt tailorable standards for software development, management, acquisition, and assurance.																		
RESPONSIBILITY: Code QR																		
ACTIVITY / MILESTONE	FY89			FY90			FY91			FY92			FY93			FY94		
Develop standard for software development											▽							
Develop standards for software management and acquisition											▽							
Develop standard for software assurance												▽						
Review and approve standards												▽			▽			
Issue policies requiring use of the standards (Administrator)															▽			

Appendix A — Schedule

<p>GOAL 1: Develop and adopt a set of agency-wide software policies and standards to support the use of Ada and state-of-the-art software engineering.</p> <p>OBJECTIVE 1.3: For any "critical" software project, require management to develop and implement a risk management plan.</p> <p>RESPONSIBILITY: Code QR</p>												
ACTIVITY/MILESTONE	FY89		FY90		FY91		FY92		FY93		FY94	
Develop criteria for "critical" software projects				▽								
Develop format and content of risk management plans				▽								
Review and approve description										▽		

Appendix A — Schedule

GOAL 1: Develop and adopt a set of agency-wide software policies and standards to support the use of Ada and state-of-the-art software engineering.																		
OBJECTIVE 1.4: Evolve toward a common software support environment.																		
RESPONSIBILITY: Code RC																		
ACTIVITY/MILESTONE	FY89			FY90			FY91			FY92			FY93			FY94		
Produce report on high-level environment						▽												
Start research into concepts of the environment						▽												
Specify functional capabilities of NASA environment										▽								
Produce prototype system														▽				

Appendix A — Schedule

<p>GOAL 1: Develop and adopt a set of agency-wide software policies and standards to support the use of Ada and state-of-the-art software engineering.</p> <p>OBJECTIVE 1.5: Establish an Ada incentive program for NASA software contractors.</p> <p>RESPONSIBILITY: Code H</p>																								
ACTIVITY/MILESTONE	FY89			FY90			FY91			FY92			FY93			FY94								
Develop plan for incentive program						▽																		
Develop policy on award fees as incentives									▽															
Develop policy on incentives for acquiring new tools and methods									▽															
Develop policy on incentives for training									▽															
Develop policy on incentives for reuse									▽															

Appendix A – Schedule

GOAL 2: Use Ada as the programming language for all mission software.

OBJECTIVE 2.1: Carry out a phased transition at each center.

RESPONSIBILITY: Code NT

ACTIVITY/MILESTONE	FY89	FY90	FY91	FY92	FY93	FY94
Develop NASA three-phase plan						
Produce center transition plans (Center Directors)						
Demonstrate Phase 1 project activities (Center Directors)						
Demonstrate Phase 2 project activities (Center Directors)						
Demonstrate Phase 3 project activities (Center Directors)						

Appendix A — Schedule

GOAL 3: Establish an infrastructure to support software engineering, including the use of Ada, and to leverage the agency's software experience.																		
OBJECTIVE 3.1: Establish a Software Engineering and Ada Implementation Task Force.																		
RESPONSIBILITY: Code NT (specifically, the IRM Council)																		
ACTIVITY/MILESTONE	FY89			FY90			FY91			FY92			FY93			FY94		
Define characteristics and responsibilities of SEAITF						▽												
Establish SEAITF						▽												
Reevaluate need for SEAITF																▽		
Report progress of transition at centers													▽				▽	
Decide to terminate or extend SEAITF																	▽	

Appendix A — Schedule

GOAL 3: Establish an infrastructure to support software engineering, including the use of Ada, and to leverage the agency's software experience.																		
OBJECTIVE 3.2: Establish a Software Process Engineering Task Force to support the evaluation and improvement of the agency's software acquisition and in-house development processes.																		
RESPONSIBILITY: Code NT (specifically, the IRM Council)																		
ACTIVITY/MILESTONE	FY89			FY90			FY91			FY92			FY93			FY94		
Define characteristics and responsibilities of SPETF						▽												
Establish SPETF						▽												
Complete training						▽												
Develop plan for carrying out internal assessments						▽												
Complete first internal assessment																▽		

Appendix A — Schedule

GOAL 4: Build the agency's knowledge base in Ada and software engineering.																			
OBJECTIVE 4.1: At the agency level, plan and coordinate software research and development, more of which should pertain to Ada.																			
RESPONSIBILITY: Code RC																			
ACTIVITY/MILESTONE		FY89			FY90			FY91			FY92			FY93			FY94		
Enhance NISE program to include Ada thrust							▽												
Review completed Ada research in NASA and produce report								▽											
Establish experimentation Research and Technology Objective and Plans										▽									
Demonstrate application of research results to a NASA mission													▽						

Appendix A — Schedule

GOAL 4: Build the agency's knowledge base in Ada and software engineering.																		
OBJECTIVE 4.2: Develop and implement an agency-wide core curriculum in software engineering and Ada. Each center should adapt the core curriculum to its specific requirements.																		
RESPONSIBILITY: Code ND																		
ACTIVITY/MILESTONE	FY89			FY90			FY91			FY92			FY93			FY94		
Develop overall training program plan						▽												
Define agency-wide core curriculum									▽									
Define tracks for NASA software personnel											▽							
Implement training program at first center													▽					

GOAL 4: Build the agency's knowledge base in Ada and software engineering.																			
OBJECTIVE 4.3: Establish an agency-wide program to collect and use software metrics.																			
RESPONSIBILITY: Code NT																			
ACTIVITY/MILESTONE	FY89			FY90			FY91			FY92			FY93			FY94			
Define software measurement program						▽													
Develop handbook for software measurement						▽													
Establish measurement program at centers									▽										
Complete measured baseline of classes of NASA software										▽									
Report on impact of software technology												▽					▽	▽	

Appendix B — Persons Consulted

The ASMAWG consulted the following persons in preparing this report:

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Marvin Zelkowitz, University of Maryland

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McGarry, F., et al. (March 1989), *Ada and Software Management in NASA: Assessment and Recommendations*. Greenbelt, MD: Goddard Space Flight Center.

Reifer, D. (December 1987), "Ada's Impact: A Quantitative Assessment," *Proceedings of the 1987 ACM SIGAda International Conference*. New York: ACM.

Glossary of Acronyms

ASMAWG	Ada and Software Management Assessment Working Group
FY	fiscal year
IRM	Information Resources Management
NASA	National Aeronautics and Space Administration
NISE	NASA Initiative in Software Engineering
NMI	NASA Management Instruction
SEAITF	Software Engineering and Ada Implementation Task Force
SEL	Software Engineering Laboratory
SPETF	Software Process Engineering Task Force
SSE	Software Support Environment

